Estimating the Value of Decisions Relating to Managing and Developing Software-intensive Products and Projects

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ABSTRACT

The software industry's current decision-making relating to product/project management and development is largely done in a value neutral setting, in which cost is the primary driver for every decision taken. However, numerous studies have shown that the primary critical success factor that differentiates successful products/projects from failed ones lie in the value domain. Therefore, to remain competitive, innovative and to grow, companies must change from cost-based decision-making to value-based decision-making where the decisions taken are the best for that company's overall value creation. Our vision to tackle this problem and to provide a solution for value estimation is to employ a combination of qualitative and machine learning solutions where a probabilistic model encompassing the knowledge from different stakeholders will be used to predict the overall value of a given decision relating to product management and development. This vision drives the goal of a 3-year research project funded by the Finnish Funding Agency for Technology and Innovation (Tekes), with the participation of several industry partners.

Categories and Subject Descriptors

H.4.2 [**Types of Systems**]: Decision support.

General Terms

Management, Measurement, Economics, Experimentation.

Keywords

Value-based decision making, software product and project management, Bayesian network, value-based software engineering

1. INTRODUCTION

In today's cutthroat product and services industries, software has become the main driver for competitive advantage, enabling faster and cheaper innovation and product differentiation with no domain restriction. As the size and complexity of software-based solutions increase, so does the impact of software development decisions on the overall product offering. That is, any decision taken regarding software product/project management and development (e.g. what features to design, what level of quality to offer, or which technology to choose) will impact the entire product's/project's life cycle and value, not to mention that it limits future possibilities and direction of both the software and the business. Numerous companies worldwide deliver software intensive products and services. One of their major challenges is caused by often taking product/project management decisions considering only short-term costs (cost estimates) while ignoring long-term value aspects such as sustainability and innovation. To sustain growth, maintain competitive advantage and to innovate, such companies must make a paradigm shift by also adopting long-term value aspects in order to guide their decision-making. Such need is clearly pressing in innovative industries, such as ICT. We put forward that there are three research challenges that need to be addressed to support the software-intensive industry make this paradigm shift:

Challenge 1. The importance of a consolidated view of value considerations by different stakeholders. Companies that develop software-intensive products and services, and want to sustain growth and maintain their competitive advantage must make decisions based on a consolidated view of value that contains considerations (e.g. usability, market value size, architecture value) from different perspectives (e.g. financial, customer, innovation). Such a consolidated view is vital for two reasons: i) it can be used by professionals to develop a common understanding of value; ii) it can be employed as a decision support vehicle so all relevant value perspectives are accounted for when taking management and development decisions.

Solution to this first challenge: a company-specific consolidated inventory of value considerations must be available for use by the different stakeholders.

Challenge 2. Modelling and quantification of uncertainty. The knowledge domain relating to product/project management and development is a complex domain where decisions have an uncertain nature. The literature in the field of decision-making advocates that a suitable solution to support decision-making under uncertainty is to build models that make explicit decision makers' mental models as they can be used to compare different decision scenarios and hence provide better understanding of the situation at hand (e.g. [4]).

Solution to this second challenge: create models that explicitly represent decision makers' mental models and the domain's inherent uncertainty.

Challenge 3. Utilising decision-making models towards knowledge creation. Decisions (how one sees, thinks, or acts in the world) are influenced by decision makers' mental models; therefore, updating and enriching these mental models will lead to an improved decision-making process. Mental models, (a.k.a. representations and cognitive maps) are enhanced through the use of a knowledge creation process. Such a process is comprised of four different stages detailed as follows [13]: i) tacit to tacit, where experiences, skills and expertise are shared between individuals; ii) tacit to explicit, where tacit knowledge is 'translated' by a group into an explicit (tangible) representation; iii) explicit to explicit, where explicit knowledge from different groups is gathered, combined, edited, an diffused; and iv) explicit to tacit, where explicit knowledge is absorbed by individuals in groups within an organisation via action and practice, thus enhancing those individuals' mental models. Knowledge creation is meant to be a continuous process traversing all four stages as an integral part of it.

Solution to this third challenge: Any support to a decision-making process must also include a knowledge creation process.

Our vision towards estimating the value of decisions within the ICT domain is to address collectively all three research challenges abovementioned using a combination of qualitative and machine learning solutions to build probabilistic value estimation models with tool support. The successful realization of such vision is the focus of a 3-year research project funded by the Finnish Funding Agency for Technology and Innovation (Tekes).

Such models will cater for the specific needs of our industry partners and support them in making a paradigm shift to value-based decision-making. The models represent the decision makers' mental models and the uncertainty inherent to their knowledge domain, created using the knowledge management technique called *Bayesian Network*. This technique incorporates the four stages of a knowledge creation process, and the knowledge to be embedded into these models will represent company-specific consolidated views of value considerations when making decisions relating to software product/project management and development by the stakeholders. Note that no previous work to date has proposed *company-specific consolidated views of value considerations* and the use of such consolidated views as input to building value estimation models.

Our goal is that all models will provide *estimates of the overall value* for a company to implement a decision scenario relating to software product/project management within the domains of ICT and digital services, and *"what-if" scenarios* that can be compared and contrasted, thus enabling better decision-making and contributing to enhanced decision makers' mental models (tacit knowledge).

2. BACKGROUND

2.1 Value-based decision making

Previous studies have proposed value considerations and corresponding measurement solutions needed for making decisions about software product management and development (e.g. [2][3]). An extensive systematic mapping review where 364 referred research papers investigating value aspects within the context of software engineering revealed that these contributions were often isolated and with a limited perspective [8]; thus, a complete picture of value considerations relevant from different perspectives and for different stakeholders, for use to take software product management and development decisions, was missing. As a contrast to such approaches, Khurum et al. proposed a large classification of ~50 value perspectives using as basis the work from [8] and also additional literature from economics, business and marketing research. They argue that such classification is detailed enough to represent the views of all the different stakeholders who make decisions relating to software products; however, our prior experience in knowledge elicitation for building cost estimation models [11] showed that the use of a very detailed classification of factors that require considerable training in order to be used during knowledge elicitation leads to industry's disengagement from collaborating. Therefore we believe that the value aspects important for an organisation should be co-created from the start.

2.2 Knowledge Management

At the heart of an organisation's ability to sustain its competitive advantage and to innovate is the knowledge it holds, and its capability to learn and utilise such knowledge [6]. Sustainable organisational improvement requires a "commitment to learning", where knowledge management is seen as an enabler of organisational learning [6]. However, despite the core of what software organisations do is knowledge intensive, their use of knowledge management activities is still lacking, and some distance away from changing them into learning organisations [6].

There are numerous knowledge management techniques available, and we selected the technique called Bayesian Network (BN) for the following reasons: i) it has been successfully employed for decision-making under uncertainty in several complex domains (e.g. genetics, speech recognition, medical diagnosis, software project management) [5]; ii) it supports reasoning under uncertainty from the way it incorporates knowledge of a complex domain [9]; iii) it is the most appropriate choice when compared to robust decision methods as it enables the representation of well-characterized uncertainty and manageable decision options, which is the case herein; iv) it enables reasoning under uncertainty and combines the advantages of an intuitive visual representation with a sound mathematical basis in Bayesian probability [9]. v) it incorporates the four stages of a knowledge creation process [13]; and vi) we have previously applied BN successfully to support decision-making under uncertainty in three other complex domains - software resource estimation, software risk management and software requirements prediction - all collaborations with numerous industry partners worldwide [11][12]. This technique (detailed further in Section 3) provides a solution to research challenges 2 and 3, detailed in Section 1.

3. Realising our Vision for Value Estimation

Within the context of our research, BN models are used to represent domain knowledge in terms of value factors deemed important when making decisions that relate to software product and project management and development. Figure 1 shows a very small example of a BN model, which represents an example scenario where different stakeholders are deciding upon the set of features to be selected for implementation in the current product's release. The model shows three factors: i) Overall value, which represents the overall impact associated with implementing a given feature into an existing product; ii) 'Customer Retention' and 'Customer Satisfaction', which represent value factors used by the stakeholders during decision making meetings to help them decide upon which features to select for implementation for a given product release.

Figure 1 also shows two arrows, pointing from the customer-related factors towards the 'Overall Value' factor. Every arrow in a BN model represents a cause & effect relationship between the factor that is the arrow's origin and the one that is the arrow's destination, respectively. What this means is that any type of impact relating to the value factors 'Customer Retention' and 'Customer Satisfaction' will have an effect upon 'Overall Value'.

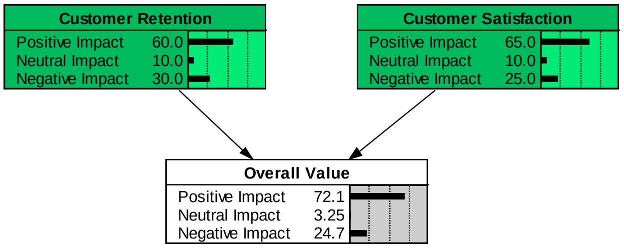

Figure 1. Example very small Value estimation model.

CPT for factor Customer Retention

Positive Impact	Neutral Impact	Negative Impact
60	10	30

CPT for factor Customer Satisfaction

Positive Impact	Neutral Impact	Negative Impact
65	10	25

CPT for factor Overall Value

Customer Retention	Customer Satisfaction	Positive Impact	Neutral Impact	Negative Impact
Positive Impact	Positive Impact	100	0	0
Positive Impact	Neutral Impact	95	5	0
Positive Impact	Negative Impact	60	0	40
Neutral Impact	Positive Impact	95	5	0
Neutral Impact	Neutral Impact	50	50	0
Neutral Impact	Negative Impact	0	10	90
Negative Impact	Positive Impact	60	5	35
Negative Impact	Neutral Impact	0	30	70
Negative Impact	Negative Impact	0	0	100

Figure 2. CPTs for factors shown in Figure 1.

Further, every factor in a BN model has an associated table (CPT :Conditional probability table) that quantifies probabilistically numerous decision making scenarios (example tables are shown in Figure 2). The two CPTs relating to the factors 'Customer Retention' and 'Customer Satisfaction' show the aggregated frequencies, for all the stakeholders participating in the past *n* decision making meetings, associated with each of the features that were selected over a given period (e.g. the timeline relating to the previous release of this same product). Figure 2 shows that 60% of the features that were implemented in the previous release were judged to have a positive impact upon the retention of customers, if implemented in the existing product; 10% of the features were judged to have a neutral impact upon the retention of customers, 65% were judged to have a positive impact upon customer satisfaction, and so on. With regard to the factor 'Overall value', given that this factor is affected by the other two, its CPT will represent quantifications that are conditional upon the other factors' states. For example, Figure 2 shows that the overall value that a given feature will bring to the existing product will be 100% positive if this feature was judged to bring a positive impact to both 'Customer Retention' and 'Customer Satisfaction', and so on. These frequencies and probabilities are the means used in BNs towards the probabilistic quantification of the uncertainty related to decision-making in the domain being modeled. The overall process we use when building BN models is detailed in [11]. BNs can be built solely from data, from domain expertise, or using a combination of both. In our previous work, we built such models based only on domain expertise; however, the time it takes to build the CPTs can be prohibitive, thus we have investigated ways towards the semi-automatic generation of probabilities [1]. Further research in this area is also the focus of our research (see Activity A.3 in Figure 3) as this is an important enabler to building value estimation models for the wider use by the ICT industry for decisions relating to software product and services management and development.

The main Activities to achieve our vision are shown in Figure 3, and detailed as follows:

A1 – Elicit company-specific Value aspects: This activity focuses on the solution to challenge 1 and employs a qualitative research approach, where stakeholders are interviewed individually, and their interviews later transcribed and analysed using Grounded Theory principles [14]. This is followed by focus group meetings to discuss all the value factors (value aspects) elicited, so to obtain a common set of factors and a common understanding of all the factors that were identified. In Figure 3 we used a made-up example where factors were arranged according to the balanced scorecard perspectives; however, the set of value factors considered important by a company will be determined by the stakeholders based on their own context and experience.

A2 – Use the results from A1 with tool support for decision-making meetings: This activity represents the use of our first generation tool in order to enable different stakeholders to employ their value factors when participating in decision making meetings. The tool, which is distributed, supports the representation of value factors by stakeholders, the measurement of each factor, aggregation of stakeholders' decisions via a dash board providing different data visualisation techniques, storage of decisions per meeting, the rationale associated with each decisions, comparison of different stakeholders' views etc. Our goal with this tool is twofold: first, to gather data on decisions, to be used at a later stage to build value estimation models; and second, to provide companies with a mechanism to get them engaged in thinking in this new value-based paradigm, and as a consequence to make a paradigm shift from a cost-based to a value-based approach to decision making.

A3 - Semi-automatic generation of probabilistic value estimation models: This activity encompasses the proposal and comparison of several algorithms for the semi-automatic generation of probabilities for CPTs that belong to child nodes (a child node is a factor that is pointed at by an arrow in a BN model). As this is a semi-automatic approach, stakeholders are also taking part in meetings and different walking through scenarios in order to decide upon the best solution (algorithm). The decisions database will provide the frequencies for the factors that are not pointed out by any arrows (parent nodes using a BN jargon). Note that all BN models are company-specific.

A4 – Validation of estimation models: This activity represents the use of the value estimation model(s) during decision making meetings, and their comparison to stakeholders' individual and model-independent assessments.

A5 – Use in decision-making meetings: This activity entails the replacement of our first generation tool by our second generation tool (BN model), which will also be a distributed tool, to be used for decision making by all the stakeholders.

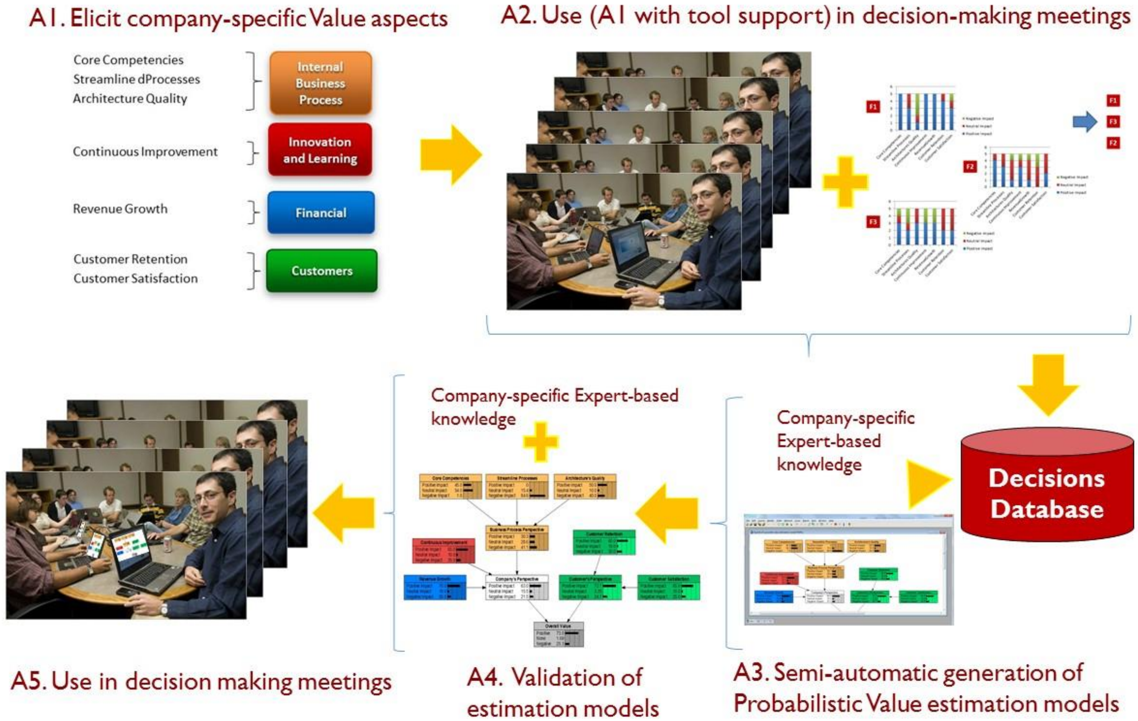

Figure 3. Main Activities towards achieving our vision.

Note that activities A2 to A5, when combined, also represent the four different steps of a knowledge creation process [13], so contributing towards achieving our third research challenge.

We have currently four industry partners with whom these activities are taking place since January 2015, and aim to engage further partners as the project progresses.

4. CONCLUSIONS

This short paper has presented our vision towards a value-based decision making approach that can be used to estimate the value associated with decisions relating to the management and development of software intensive products and services.

5. ACKNOWLEDGMENTS

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